MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EMF4066 – RF CIRCUIT DESIGN
(TE)

4 MARCH 2019
2:30 P.M. – 4:30 P.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Explain briefly the usage of attenuator in a typical communication system. State the differences between attenuator and amplifier.

[5 marks]

(b) Two cascaded attenuators are used to reduce the source voltage to load R_L, as shown in Figure Q1(a). It is required that the image impedance looking into the input of the attenuator be equal to the load resistor.

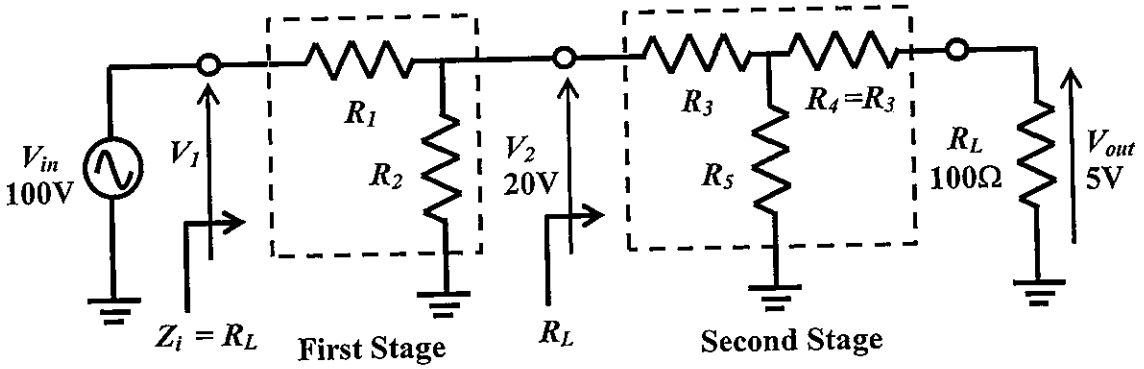

Figure Q1(a)

(i) Name the type of attenuators used in the first and second stages.

[2 marks]

(ii) For each stage, determine the attenuation factor (in dB). What is the total attenuation factor (in dB) for this cascaded system?

[3 marks]

(iii) Calculate the values of R_1, R_2, R_3, R_4 and R_5.

[5 marks]

(c) A quarter-wave matching transformer to match a 40 Ω load to a 75 Ω lossless transmission line is to be designed as shown in Figure Q1(b)

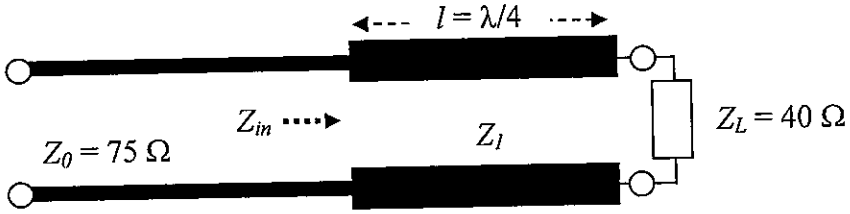

Figure Q1(b)

(i) State TWO (2) advantages and TWO (2) disadvantages of using quarter-wave matching transformer in impedance matching.

[4 marks]

Continued .....

(ii) Show that the input impedance of the quarter-wave matching transformer,

$$Z_{in} = \frac{Z_1^{\,2}}{Z_L}$$

where Z_1 is the characteristic impedance of the quarter-wave transformer
[4 marks]

(iii) Determine Z_1.
[2 marks]

Question 2

(a) State FOUR (4) advantages of stripline over its microstrip lines counterpart in planar printed circuit board (PCB) implementations.
[4 marks]

(b) What are the dominant modes of propagation in microstrip and stripline transmission lines?
[2 marks]

(c) Consider a microstrip resonator constructed from a half-wavelength ($\lambda/2$) length of 50 ohm open-circuited microstrip line. The substrate is Teflon (relative permittivity $\varepsilon_r = 2.08$), with a thickness of 0.159 cm. The conductors are copper. Determine the length (l) of the line for resonance at 5 GHz.
*(**Hints** – Use the microstrip equations listed in Appendix and assume W/d > 2)*
[8 marks]

(d) A GaAs FET has the following S – parameters at 2 GHz ($Z_o = 50\Omega$):

$S_{11} = 0.894\angle{-60.6°} = 0.439 - j0.779$,
$S_{21} = 3.122\angle{123.6°} = -1.728 + j2.600$,
$S_{12} = 0.02\angle{62.4°} = 0.00926 + j0.0177$, and
$S_{22} = 0.781\angle{-27.6°} = 0.692 - j0.362$.

(i) Calculate the Rollette stability factor k and Δ, and state the stability condition.
[3 marks]

(ii) Determine the center C_{out} and radius r_{out} of output stability circle
[4 marks]

(iii) Determine the center C_{in} and radius r_{in} of input stability circle.
[4 marks]

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Question 3

(a) A filter has the S_{21} (in dB) shown in Figure Q3. It is measured from approximately 400 MHz to 1200 MHz, with a 50 Ω reference impedance (Z_0).

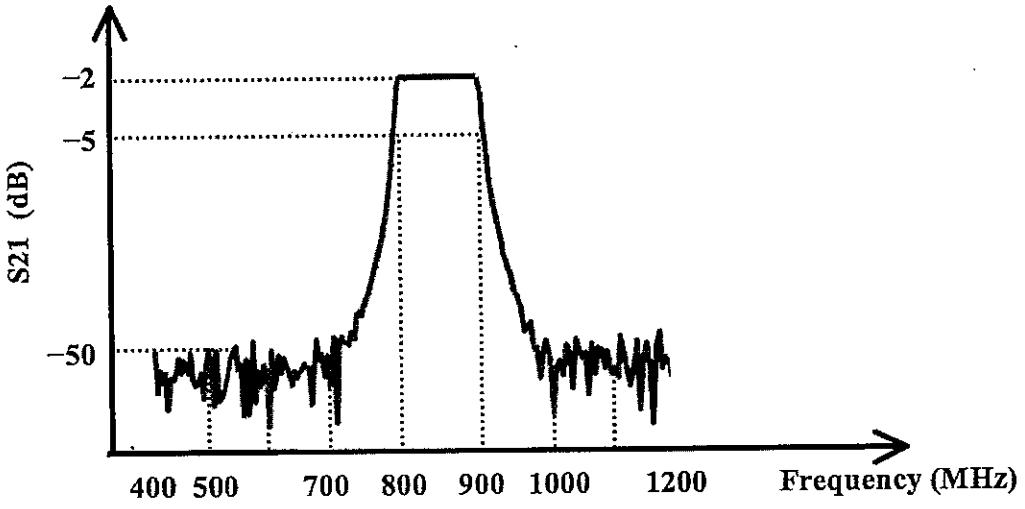

Figure Q3

(i) What type of filter is shown in the above measurement?

[1 mark]

(ii) Determine the insertion loss, cut-off frequencies, center frequency and 3 dB bandwidth of the filter.

[5 marks]

(iii) What are the stop-band frequencies and rejections of the filter?

[4 marks]

(b) Design a stepped-impedance low-pass filter having a maximally flat (Butterworth) response and a cutoff frequency of 2.5 GHz. It is necessary to have more than 20 dB attenuation at 3.75 GHz. The filter impedance is 50 Ω, the highest practical impedance is 120 Ω and the lowest is 20 Ω. Consider the filter is implemented with a microstrip FR-4 substrate (thickness, d = 0.158 cm and relative dielectric constant, ε_r = 4.2). Calculate all the required electrical lengths (βl_i) along with the physical microstrip line widths (W_i) and lengths (l_i).

[15 marks]

Continued .....

Question 4

(a) Explain briefly THREE (3) difficulties encountered in the design of a broadband amplifier.

[6 marks]

(b) Draw THREE (3) resistive negative feedback topologies for both the Bipolar Junction Transistor (BJT) and Field Effect Transistor (FET) for broadband amplifier.

[6 marks]

(c) Design a 30 dBm multistage power amplifier for linear operation at 4 GHz, using the transistor choices listed in Table Q4. The input signal power is –5dBm.

[G_p – power gain, $P_{out,\,1\,dB}$ / G_{1dB} – Output power/gain at 1dB compression point]

Table Q4

Transistor	G_p [dB]	$P_{out,\,1\,dB}$[dBm]	G_{1dB} [dB]
ATF-44101	10	32	9
ATF-45101	11	29	10
ATF-25570	14	20.5	13

(i) Find the required power gain for this multistage amplifier?

[2 marks]

(ii) Determine the number of stages required for this multistage amplifier.

[2 marks]

(iii) Which transistor is suitable for the first stage? Explain your answer.

[2 marks]

(iv) Which transistor is suitable for the last stage? Explain your answer.

[2 marks]

(v) Calculate the power gain and output power obtained from this design.

[2 marks]

(vi) Sketch this multistage design and indicate the gain and power levels of each stage.

[3 marks]

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Appendix – Useful Formulas

Microstrip equations for dielectric constant and characteristic impedance

- The effective dielectric constant of a microstrip line is given by:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \cdot \frac{1}{\sqrt{1 + 12d/W}}$$

- Given the dimensions of microstrip line, characteristic impedance can be calculated as:

$$Z_0 = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_e}} \ln\left(\dfrac{8d}{W} + \dfrac{W}{4d}\right) & for \quad W/d \le 1 \\ \dfrac{120\pi}{\sqrt{\varepsilon_e}\left[\dfrac{W}{d} + 1.393 + 0.667 \ln\left(\dfrac{W}{d} + 1.444\right)\right]} & for \quad W/d \ge 1 \end{cases}$$

- For a given characteristic impedance and dielectric constant, the W/d ratio can be found as:

$$\frac{W}{d} = \begin{cases} \dfrac{8e^A}{e^{2A} - 2} & for \quad W/d < 2 \\ \dfrac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \dfrac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B - 1) + 0.39 - \dfrac{0.61}{\varepsilon_r}\right\}\right] & for \quad W/d > 2 \end{cases}$$

where

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\varepsilon_r}}$$

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Figure 1 – Attenuation versus normalized frequency for Butterworth prototypes

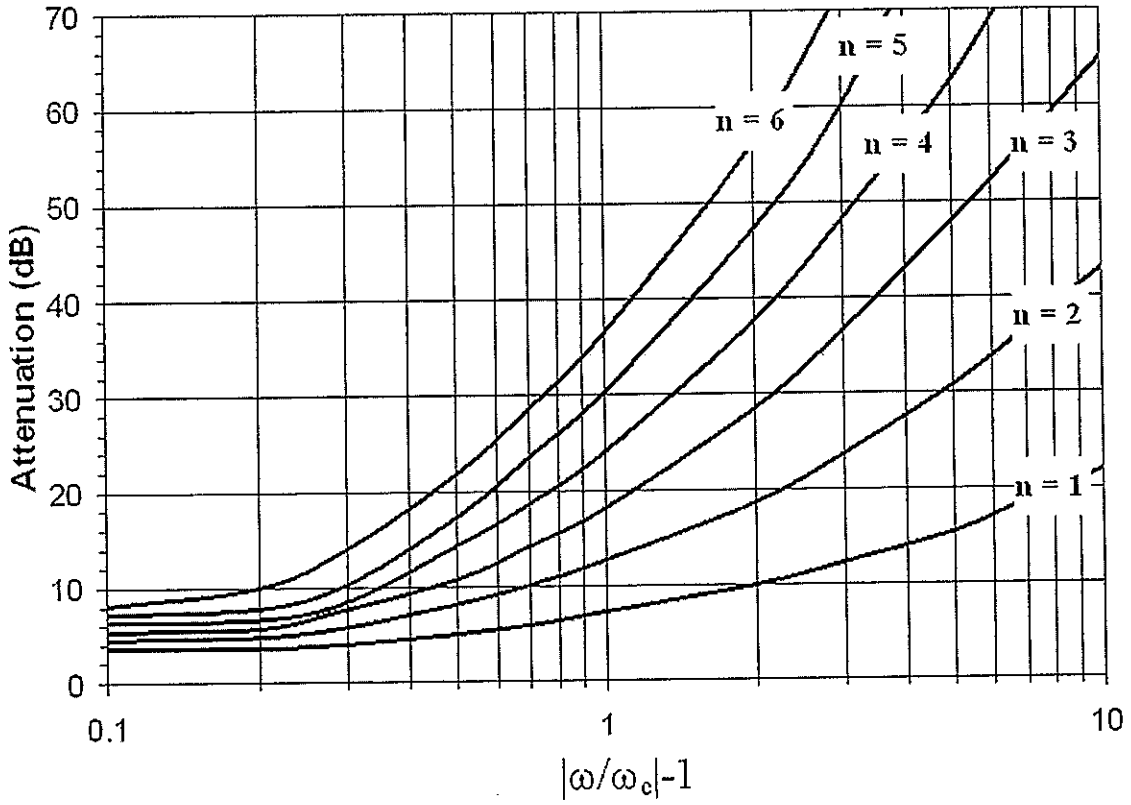

Table 2 – Element values for Butterworth Low-Pass Filter Prototype

N	g1	g2	g3	g4	g5	g6	g7
1	2.000	1.000					
2	1.414	1.414	1.000				
3	1.000	2.000	1.000	1.000			
4	0.765	1.848	1.848	0.765	1.000		
5	0.618	1.618	2.000	1.618	0.618	1.000	
6	0.517	1.414	1.932	1.932	1.414	0.517	1.000

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